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Combined electronic fetal heart rate and fetal movement monitor – a preliminary report

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1 Introduction

The biophysical profile as described by MANNING et al in 1980 is based on fetal breathing movements, fetal movements, fetal tone, the amount of amniotic fluid volume and a nonstress test [10]. Evaluation of these five variables showed that fetal movement was the most accurate single indicator of fetal well-being [12, 15, 18]. Fetal movement is best verified by continuous real time ultrasound observation. Other methods are maternal perception, piezoelectrodes, tocometry, or Doppler ultrasound [1–3, 5–8, 11, 14, 16, 17, 20–22]. The Actocardiograph (Toitu, Tokyo, Japan) described by MAEDA [9] in 1984 utilizes the latter method.

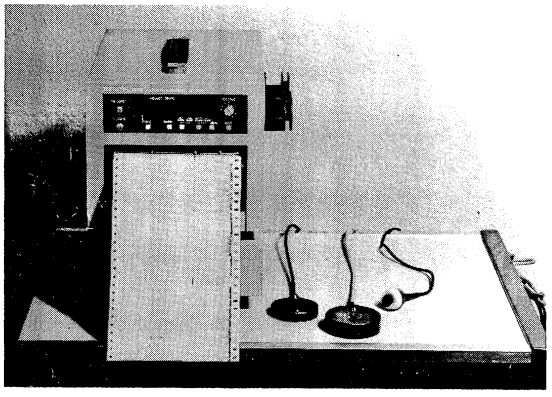


Figure 1. Actocardiograph MT 320, a new Doppler ultrasound equipment to recognize fetal heart rate and fetal movements.

Curriculum vitae

ELIANE SCHWÖBEL, *M. D., graduatd from the Medical School of the University of Zurich (Switzerland) in 1979. In 1981 she joined the Departments of Obstetrics and of Gynecology at the University hospital in Zurich. Since 1985 she has been attached to the Perinatal Physiology Research Laboratory in the Department of Obstetrics. One of her main interests is obstetrical ultrasound.*

We have had the opportunity to evaluate the first examples of this apparatus available in Europe (figure 1). It is as easy in handling as other fetal heart rate monitors on the market. It is smaller and lighter than most.

The aim of this study was, firstly to verify the movements registered by the Actocardiograph by real time ultrasound observation; secondly, to observe the correlation between fetal heart rate accelerations and fetal movements; and finally, to investigate whether maternal behavior interfered with the Doppler registration of the movements.

2 Material and methods

The recording of fetal movements is achieved by the same transducer as that used for fetal heart rate. Fetal heart rate is obtained from the

more rapid Doppler shifts, i. e. above 80 Hz. In the usual fetal heart rate monitors the lower frequencies are suppressed. In the Actocardiograph frequencies below 80 Hz are filtered into two separate channels indicating fetal movements.

The lowest channel has a continuous noise and according to MAEDA only peaks above 30 on the arbitrary scale indicate fetal movement [9]. In the middle channel is indicated by a dot or a line if there are peaks above 30 in the lowest channel. This middle channel may alternatively be used for event marking, for instance, of movements observed by real time ultrasound. The amplitude in the bottom channel is proportional to the movement. Short movements are registered as one signal. Longer lasting movements such as rotations result in two or more peaks [9].

The Actocardiograph was tested on 20 women with normal pregnancies between the 30th and 42nd week of gestation (4 cases 30th – 33rd, 4 cases 33rd – 36th, 5 cases 36th – 39th and 8 cases between 39th and 42nd weeks). Subsequent deliveries were uncomplicated and the infants were healthy. Observation was made between 9 a. m. and 5 p. m. and lasted 45 minutes. The mothers were almost supine but somewhat tilted to the left.

As the instrument basically is a fetal heart rate monitor its transducer must be placed over the fetal heart. Fetal movements were simultaneously visualized by real time ultrasound (Toshiba SAL-20, 3,5 HMz) by placing its transducer immediately below that of the Doppler. By this arrangement only trunk movements, mainly rotations but also extentions and flexions, can be observed. Isolated limb movements will not be seen.

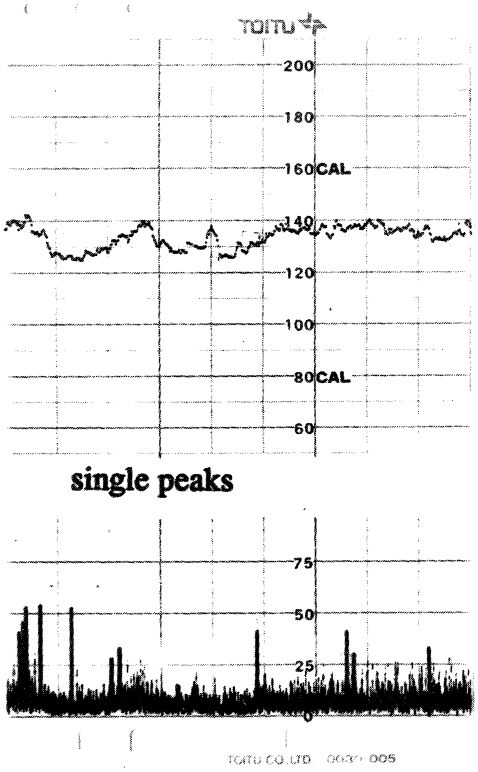
Each registration of the 20 women was evaluated in 90 segments of 30 seconds each. Two separate calculations were made, one looking at the single peaks and the other counting clusters. The latter were defined as ten or more peaks per 30 seconds (figure 2). The movements seen by ultrasound were registered in the middle channel and compared to the peaks in the lowest one. The registered movements were divided in three intensity levels (30 – 49, 50 – 74, 75 – 100) using the scale on the chart of the Actocardiograph. From this, true positive, false positive and false negative events were obtained and the positive predictive value and the sensitivity were calculated. For these calculations it was assumed that the real time ultrasound observation gave an objective information about fetal movements. Such assumptions practically always have to be made when calculating predictivity and sensitivity. Similarly the real time ultrasound movements were compared with fetal heart rate accelerations, the latter been defined as increases of $\geq$ 15 beats per minute lasting $\geq$ 10 seconds.

The influence of the following factors on movement recognition were checked: gestational age, amount of amniotic fluid, position of the placenta, fetal and maternal breathing movements, maternal talking, laughing, coughing and hiccups.

3 Results

During the total monitoring time of 15 hours, 263 clusters were noted. These clusters always coincided with observed fetal movements. In the individual record the number of clusters ranged from 0 to 37 in the 45 minutes observation period. Therefore no useful mean value can be given.

The positive predictive value of all peaks was 0.93, i. e. 93% of registered movements were seen by real time ultrasound and 7% were false positive registrations. The sensitivity was 0.94, i. e. 94% of all movements seen by real time ultrasound were registered by the Actocardiograph and 6% were not registered. In order to obtain the frequency of the fetal movements they were calculated as numbers of events per hour. The average number of individual peaks per hour was 73. As a longer movement may be represented by two or more peaks the actual number of movements cannot be given. Five events per hour were falsely positive. With higher intensity the predictive value was in-



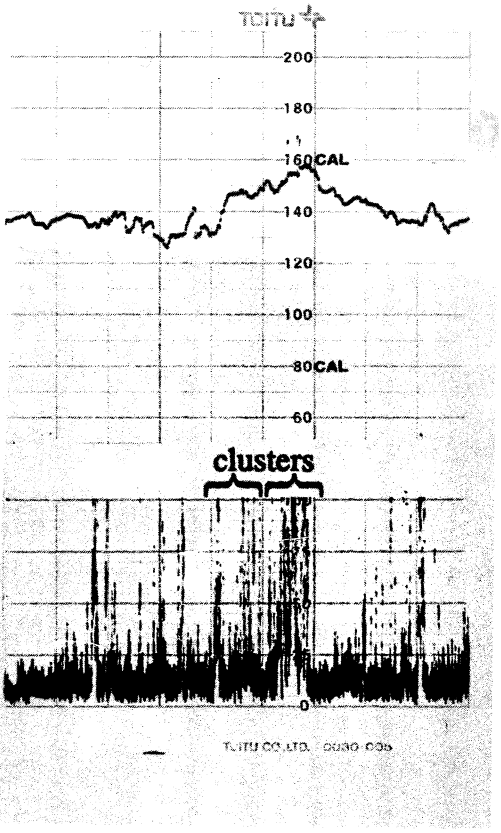


Figure 2. Single peaks (left); two clusters (right).

creased and at the same time the sensitivity was reduced (figure 3). As expected the probability that a movement is seen but that the signal does not reach the higher arbitrary limits rises proportionally to the intensity level.

The positive predictive value of the acceleration of the fetal heart rate as indication of fetal movements was 0.87 and the sensitivity was 0.85.

Neither the gestational age nor the amount of amniotic fluid nor the position of the placenta had any influence on the registration of fetal movements, whereas maternal coughing and hiccups were recorded as movements by the Actocardiograph.

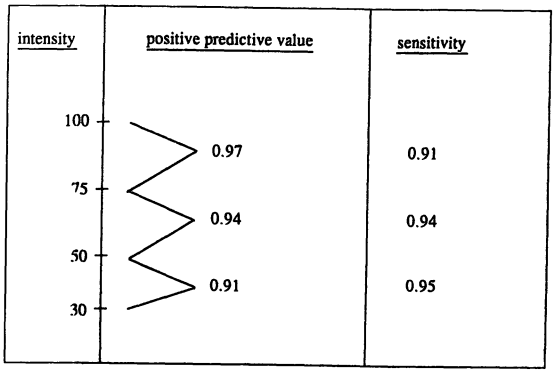


Figure 3. The positive predictive value and the sensitivity in relation to the intensity of the movements in arbitrary scale units.

4 Discussion

We have observed a good agreement between the fetal movements seen by the real time ultrasound and these movements registered by the Actocardiograph. By visualizing the lower fetal thorax with only one transducer isolated limb movements cannot by detected. SCHMIDT et al [19] with one transducer over the upper thorax and one over the legs, saw isolated leg movements in 7%. 79% of all limb movements were accompanied by trunk movements.

For clinical purposes diminished fetal activity is of special interest. If few movements are noted the fetus may be asleep and in order to ensure correct interpretation the recordings must last at least 45 minutes. PATRICK et al [13] using continuous real time observation lasting 24 hours in each of the 31 uncomplicated pregnancies between 30 and 39 weeks of gestation only in 1% of the total observation noted an absence of movements for more than 45 minutes. None of the fetuses rested longer than 75 minutes. NATALE et al [11] demonstrated in lamb fetuses that a reduction of arterial Po_2 of the maternal animal was followed by decreased number and duration of fetal movements. RICHTER [15] described neonatal difficulties of adaptation in 33% of the fetuses whose mothers had perceived less than 10 fetal movements in a 12 hour period. Furthermore these infants had a neonatal morbidity rate of 22%. When more than 10 movements were felt the corresponding rates were 3% and 5% respectively. DIANI et al [4] found a significant correlation between diminished fetal activity and fetal growth retardation. COLETTE and ANGUENOT [3] using an equipment similar to the Actocardiograph registered a mean of 8 movements per 10 minutes in 30 risk patients between the 30th and 36th week of gestation. In the same number of non-risk pregnancies between the 17th and 22nd week of gestation they found a mean of 25 movements per 10 minutes. The low number of only 10 fetal movements in 12 hours perceived by the mothers as described by RICHTER [15] to predict a favorable fetal outcome, must be only a small fraction of movements actually occuring. In the literature the maternal perception ranges between 37 and 80% [17, 19]. Although as stated the number of events recorded by the Actocardiograph is somewhat higher than the number of movements, the results obtained with the Actocardiograph is of the same order of magnitude as the quoted studies [3, 4, 13]. If only clusters are considered they always represent movements, but then the actual number of movements is underestimated.

Acceleration of fetal heart rate is usually taken as an indirect sign of fetal activity. The comparison made with the real time ultrasound observation of movements showed an acceptable positive predictive value and sensitivity, but the figures were lower than those obtained using the Toitu equipment. The low frequency Doppler shifts are a direct indication of body movements whereas the frequencies above 80 Hz representing fetal heart rate only indirectly express body movements.

The price of the Actocardiograph MT 320 is lower than that of most fetal heart rate monitors so that the additional facility of recording fetal movements is obtained without increase of cost, patient risk or complexity. The clinical usefulness of a more detailed recording of fetal movements needs to be ascertained.

Summary

We have tested a new Doppler ultrasound apparatus which registers both fetal movements and fetal heart rate with a single transducer. To evaluate the reliability of the recognition of movements we also observed them simultaneously by real time ultrasound. In 20 patients with normal pregnancies between the 30th and 42nd week of gestation, taking the real time ultrasound as reference the positive predictive value was 0.93 and the sensitivity 0.94. Maternal hiccups or coughing were recorded as fetal movements. Neither gestational age, the amount of amniotic fluid or the position of the placenta influenced the recognition of movement; nor did fetal breathing, maternal breathing, speaking or laughing.

Keywords: Doppler Ultrasound (Actocardiograph Toitu MT 320), fetal heart rate, fetal movements.

Zusammenfassung

Kombinierte, elektronische fetale Herzfrequenz- und Bewegungsregistrierung
Wir haben ein neues Doppler-Ultraschallgerät (Actocardiograph MT 320) getestet, das mit dem gleichen Transducer die fetale Herzfrequenz und die fetalen Bewegungen aufzeichnet. Um die Zuverlässigkeit der Bewegungsregistrierung zu prüfen, beobachteten wir den Feten gleichzeitig mit Realtime-Ultraschall. Wir führten die Untersuchungen bei 20 gesunden Schwangeren zwischen der 30. und 42. Schwangerschaftswoche durch. Bezogen auf die im Realtime-Ultraschall gesehenen Bewegungen betrug der positive Voraussagewert 0.93 und die Sensitivität 0.94. Mütterlicher Schluckauf und Husten wurden als fetale Bewegungen registriert. Weder das Gestationsalter, noch die Fruchtwassermenge, noch die Lage der Plazenta beeinflußten die Bewegungsregistrierung. Ebensowenig wirkten sich fetale oder mütterliche Atembewegungen, Sprechen oder Lachen auf die Aufzeichnungen aus.

Schlüsselwörter: Doppler Ultraschall (Actocardiograph Toitu MT 320), fetale Bewegungen, fetale Herzfrequenz.

Résumé

Enrégistrement électronique combiné des bruits cardiaques et des mouvements fœtaux
Nous avons evalué un nouvel appareil ultrasonographique à l'effet Doppler (Actocardiograph MT 320) qui recense avec la même sonde la fréquence cardiaque fœtale et les mouvements fœtaux. Pour contrôler la fiabilité de l'enrégistrement des mouvements, nous avons observé simultanément le fœtus avec un appareil ultrasonographique «Realtime». Vingt patientes ont été examinées entre la 30ième et la 42ième semaine de grossesse. Comparée à l'appareil ultrasonographique, la valeur de prédiction et la sensitivité se situaient à 0,93, respectivement 0,94 pour les mouvements aperçus. L'âge gestationel, la quantité du liquide amniotique et la position du placenta n'ont pas d'influence sur l'enrégistrement. Les mouvements respiratoires fœtaux et maternels, les rires et le fait de parler ne jouent également aucun rôle. Pourtant le hoquet et la toux des mères simulent des mouvements fœtaux.

Mots-clés: Actocardiograph (Toitu MT 320) à l'effet Doppler, fréquence cardiaque fœtale, movements fœtaux.

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